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ORIGINAL ARTICLE

The effect of forest treefall gap on humus forms in a mixed *Fagus orientalis* Lipsky (Oriental Beech) forest

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Abstract

Gap formation affects environmental conditions in forest ecosystems. In this study, the effect of forest gap on humus form in a mixed *Fagus orientalis* Lipsky (Oriental Beech) forest was investigated by comparing the humus forms found in gaps with those in parts of the stand with closed canopies in a temperate mixed forest in northern Iran. In total, 32 gaps were selected from which 160 humus profiles were considered within gaps, and a further 160 within adjacent closed canopies. In each profile, humus forms were determined based on their morphological characteristics. Results indicated that gap significantly affected humus forms. The humus forms in gaps differed significantly from those in adjacent areas of closed stand. Mull order type humus was the most commonly found in the study site (70% of all profiles). The results also showed that forest floor thickness was lower in gaps than in adjacent closed areas. The suborder eumull was the most common in gaps, whereas dysmull was found to be the most common within closed areas.

Key words

forest floor, oriental beech, silviculture, canopy gap

Introduction

Organic matter forms only a small fraction of most forest soils, and yet has a profound impact on their physical and chemical properties (Fisher and Binkley 2000). Decomposition of organic matter plays a vital role in nutrient cycling through which organically bound nutrients mineralize and become available for plant uptake. In infertile soils the role of the decomposition process becomes even more significant in nutrient cycling, since almost all plant-available nutrients in these ecosystems originate from plant debris (Sluiter and Smit 2001). Different types of humus forms develop within the top soil throughout the process of biotransformation of dead organic matter. Climatic conditions, soil characteristics, and vegetation type are among the variables that can affect this process (Green et al. 1993). Humus forms have been shown to have an intimate relationship with vegetation and soil characteristics, and are thus considered as one of the principal components of terrestrial ecosystems (Sajedi et al. 2004). As humus forms develop on shorter time scales than soil types, they do not necessarily coincide with one another and therefore need to be classified independently (Graefe and Beylich 2006). Humus forms may be regarded as useful indicators of ecosystem characteristics and function; as such,

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the study of humus form provides ecologically relevant information on site conditions such as availability of moisture, soil acidity and nutrient status (Van Delft et al. 2006). Humus form is primarily affected by several agents, such as plant species, climate and microclimate, topography, landform elements, and latitude etc. Microclimate is one of the most important factors in humus formation, and treefall gap is one such factor that affects the microclimate of forests. When one or more canopy trees are injured or die, oftendue to natural disturbance, small openings, or ‘gaps’, are formed in the forest canopy (Yamamoto 2000). In unmanaged forests protected from large-scale disturbances by wind or fire, gaps play a key role in regulating stand development (Runkle 1982), and are the sites of the greatest understory regeneration and recruitment (Gray and Spies 1996). Canopy gaps have been a major focus of forest ecologists, whose aim has been to understand the functioning of forest ecosystems and to provide information useful for forest management (Naaf and Wulf 2007). Gap formation has a significant effect on light, moisture, and nutrient properties of forest humus (Denslow et al. 1998). It has also been proven that gap formation significantly changes the quality and quantity of humus (Podrazsky and Remes 2006), and can therefore be an important factor in the formation of humus and its type. The effect canopy gaps have on the forest floor has been of interest to forest soil ecologists in recent years. Van Dam (2001) conducted a comprehensive study on gaps in the tropical forests of Guyana, concluding that gap formation causes edaphic conditions to change, and that this change can continue for many years. Ritter and Bjornlund (2004) studied the effect of gap formation on some soil and litter horizon properties in a semi-natural beech-dominated forest in Denmark; the results showed that gap formation caused a significant drop in the C/N ratio, and stimulated an increase in the decomposition rate in the litter horizon of forest soil. Podrazsky and Remeš (2006) assessed changes in humus forms within gaps in the canopy of a semi-natural beech stand in the Czech Republic, and found there to be marked changes in the quality and quantity of surface humus. The amount of dry matter decreased by about 25% several years after the canopy was opened, and the pH (H_2O) and content of plant-available and total nutrients was higher in the humus layers found within gaps. Sariyildiz (2008), in an investigation entitled “Effects of Gap-Size Classes on Long-Term Litter Decomposition Rates of beech, oak and chestnut at High Elevations in Northeast Turkey”, found that large forest gaps (with a diameter of more than 30 m) significantly reduced litter decomposition rates by changing environmental conditions, and in particular by decreasing soil temperature and pH which in turn reduced soil respiration rates.

In this study we assessed the effect of forest treefall gap on humus forms in a natural mixed beech forest in the north of Iran.

Material and methods

Study site

This study was conducted in parcel 32 of compartment 1 in Shast Kalate (Bahram Nia) training forest, at the Gorgan University of Agricultural Sciences and Natural Resources. The forest is mixed deciduous, with an average annual precipitation of about 650 mm. It is located in northern Iran (36° 41’ to 36° 45’ northern latitudes and 54° 20’ to 54° 24’ eastern longitudes) with an area of about 3716 ha and an altitude ranging from 100 to 1000 m above sea level (Fig. 1).

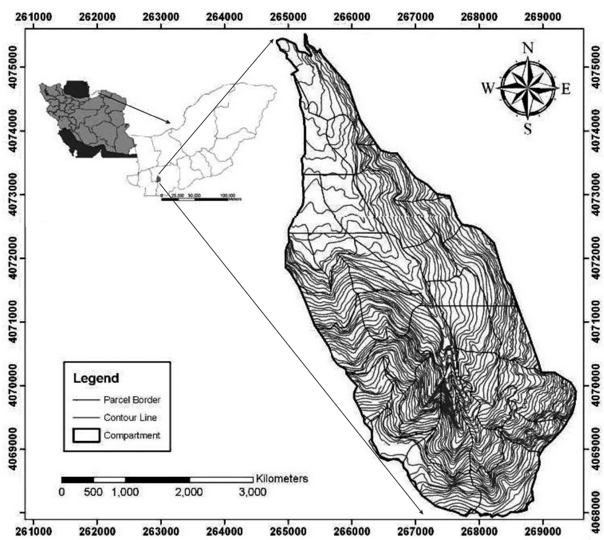

Fig. 1. Geographical position of the study site

Parcel 32 is located about 900 m asl, and is covered mostly with *Fagus orientalis* Lipsky (Oriental Beech), mixed with *Carpinus betulus* L. (Common Hornbeam), and *Parrotia persica* (DC.) C.A. Mey (Persian Iron-

wood Tree), and has an area of about 80 ha. This site is characterized by brown forest soils, with a mostly sandstone bedrock, and is a permanent plot for long term studies.

Data collection

In 2009, 32 canopy gaps were selected within the old-growth mixed beech-dominated stands. In each gap five forest floor profiles were considered, a profile at the center of gap and four other profiles in each of the cardinal directions one meter from the center. In each profile some morphological characteristics of different topsoil horizons (L, F, H, and Ah) were recorded according to the European humus classification method (Zanella et al. 2009), such as thickness, structure, color, animal or fungi activity *etc*., among which the horizons thickness and structure were the most important. The thickness was measured in mm and the structure was determined morphologically. The same profiling strategy was used in adjacent closed parts of the stand, at least 20 meters from the gap edge, and they were compared with the humus forms in gaps. In total, 320 profiles were considered (160 in gaps and 160 in parts of the stand with closed canopies). The European method (Zanella et al. 2009) was used in order to determine the humus form of the profiles examined.

Statistical analysis

All statistics were calculated with SPSS software (SPSS 2005). A Chi-Square test was used to compare humus forms of gaps with areas of adjacent forest. An Independent Sample T-test was also used to compare different horizons thickness between gaps and adjacent forest areas. The tables were drawn using EXCEL software.

Results

In all, nine different humus forms were found within the study site. The most common was dysmull at around 38% of the total; pachyamphi and eutangel were the least common at 0.6% each. Mull order humus was the most dominant overall in the study area, accounting for 70.4% of the total. The frequencies of amphi and tangel orders were 29 and 0.6% respectively (Tab. 1).

The results of the Chi-square test indicated that humus forms in gaps significantly differed from humus forms in the stand parts without gaps ($P > 0.05$) (Tab. 2).

Tab. 2. Difference of humus forms between gap and closed stand by Chi-Square

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	107.408	8	0.000
Likelihood Ratio	122.463	8	0.000
Linear-by-Linear Association	3.665	1	0.056
N of Valid Cases	320.000		

Tab. 1. Distribution of humus forms in gaps and under canopy cover

<table>
<tr><th colspan="2">Humus</th><th colspan="2">Position</th><th rowspan="2">Total</th><th rowspan="2">Percentage</th><th rowspan="2">Total percentage</th></tr>
<tr><th>Orders</th><th>Suborders</th><th>Gap</th><th>Closed stand</th></tr>
<tr><td rowspan="4">Mull</td><td>dysmull</td><td>49 (30.62%)</td><td>72 (45%)</td><td>121</td><td>37.8</td><td rowspan="4">70.4</td></tr>
<tr><td>mesomull</td><td>3 (1.87%)</td><td>0 (0%)</td><td>3</td><td>0.9</td></tr>
<tr><td>eumull</td><td>84 (52.5%)</td><td>8 (5%)</td><td>92</td><td>28.7</td></tr>
<tr><td>oligomull</td><td>6 (3.75%)</td><td>4 (2.5%)</td><td>10</td><td>3.0</td></tr>
<tr><td rowspan="4">Amphi</td><td>leptoamphi</td><td>8 (5%)</td><td>35 (21.875%)</td><td>43</td><td>13.4</td><td rowspan="4">29.0</td></tr>
<tr><td>eumacroamphi</td><td>6 (3.75%)</td><td>26 (16.25%)</td><td>32</td><td>10.0</td></tr>
<tr><td>eumesoamphi</td><td>3 (1.87%)</td><td>12 (7.5%)</td><td>15</td><td>5.0</td></tr>
<tr><td>pachyamphi</td><td>0 (0%)</td><td>2 (1.25%)</td><td>2</td><td>0.6</td></tr>
<tr><td>Tangel</td><td>eutangel</td><td>1 (0.625%)</td><td>1(0.625%)</td><td>2</td><td>0.6</td><td>0.6</td></tr>
<tr><td colspan="2">Total</td><td>160 (100%)</td><td>160 (100%)</td><td>320</td><td>100.0</td><td>100.0</td></tr>
</table>

Tab. 3. Comparison of forest floor horizon thickness between gap and closed stand by Independent Samples Test

Horizon		Levene's Test for Equality of Variances F	Sig.	T-test for Equality of Means t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
L	Equal variances not assumed	15.980	0.000	–6.032	281.226	0	–0.57500	0.09532
F	Equal variances assumed	0.961	0.328	–10.423	318.000	0	–0.57375	0.05505
H	Equal variances assumed	70.477	0.000	–6.498	318.000	0	–0.37875	0.05829
Ah	Equal variances assumed	11.448	0.001	9.181	317.000	0	2.15635	0.23488

Eumull dominated in gaps (at a frequency of 84%), but in closed regions dysmull was the dominant (72%). Also, results of the Independent Sample T-test showed that forest floor thickness in gaps was significantly lower than that of adjacent forest ($p > 0.01$) (Tab. 3). The average thicknesses of organic horizons in gaps were 1.7, 0.3, and 0.1 cm for L, F, and H respectively, compared with 2.3, 0.9, and 0.48 cm in closed parts of the stand. Within gaps the average thickness of the organo-mineral (Ah) horizon was 4.6 cm, versus 3.7 cm in closed parts of the stand (Tab. 4).

Tab. 4. The average thickness of forest floor horizons in gaps and closed

Horizons	Gap (cm)	Closed stand (cm)
L	1.7	2.30
F	0.3	0.90
H	0.1	0.48
Ah	4.6	2.50

Discussion

The soil organic horizon is one of the most important components of the forest ecosystem (Fisher and Binkley 2000; Sajedi et al. 2004; Van Delft et al. 2006; Fabianek et al. 2009; Zanella et al. 2009). Sajedi et al. (2004) investigated the humus forms in a pure beech forest in the northern forests of Iran. Their results showed that moder is the most frequent humus form in pure beech stands. However, in this study we examined a mixed stand, and considering the high proportion of mull order (70% of all profiles), it can be concluded that the presence of mull-forming tree species like hornbeam (*Carpinus betulus*), within a stand dominated by moder-forming species such as beech (*Fagus orientalis*), had a positive impact on forest floor decomposition rate with the result that mull order has become the dominant humus form. A similar effect has been observed previously by Brandtberg et al. (2000) and Aubert et al. (2006).

Eumull was the dominant humus form in gaps. Eumull form, according to Zanella et al. (2009), is one "in which all the horizons disappear, being integrated in a well amalgamated by earthworms", and its abundance in gaps demonstrates that ecological conditions for decomposition are better in these areas. Therefore gap formation in this forest ecosystem resulted in a higher decomposition rate. This higher rate is beneficial for nutrient availability, regeneration, growth, and long-term site productivity (Prescott et al. 2000; Aubert et al. 2006).

The average thicknesses of all organic horizons (L, F, and H) in closed stands were greater than in gaps; whilst the average thickness of the organo-mineral horizon (Ah) was greater in gaps. This is due to increased decomposition, and subsequently increased mineralization in gaps (Podrazsky and Remes 2006), that reduces the thickness of organic horizons and consequently increases the thickness of the Ah horizon.

Sartori et al. (2004) investigated the relationship between humus forms and soil type. They identified dysmull as the dominant humus form on parent materials of sandstone covered by brown soils. In agreement with Sartori et al. (2004), dysmull was found to be the dominant humus form in our study area.

The significant effect of gaps on quality and quantity of forest floor has also previously been reported by Podrazsky and Remes (2006) in similar ecosystems.

Conclusions

Gap formation has a significant effect on the forest floor and nature of the humus forms present. This effect, mainly caused by exposure to direct sunlight, results in a larger proportion of mull order humus and a thinner forest floor, and therefore a higher decomposition rate. In fact, forest gaps represent islands of increased decomposition rate, and in turn support higher levels of mineralization. Because of this and other factors, such as improved light availability, forest gaps represent an ideal environment for growth and regeneration, which is an important goal in close-to-nature silvicultural systems.

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